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The Editor's Page

AS of October 1st, U. S. Institute for Textile Research, Inc., commences its fifth fiscal year, although the fourth anniversary of its formal organization will fall on Thursday, November 1st, the date of our next annual meeting.

For that meeting the Hotel Pennsylvania, New York, N. Y., has been tentatively engaged, and the first session presumably will start, as heretofore, with luncheon at 12:30 P.M. Meetings of directors and committees will be held in the forenoon, starting at 10 o'clock.

Committees for the annual meeting as appointed by President Garvan are as follows:

Program—W. E. Emley, Chm., Dr. H. DeWitt Smith, Alban Eavenson, Prof. E. R. Schwarz, C. H. Clark.

Nominations—Alban Eavenson, Chm., P. A. Johnson, E. N. Hood.

Budget—E. N. Hood, Chm., William W. Buffum, C. H. Clark.

Auditor—William W. Buffum.

THE current fiscal year and the coming annual meeting, being our fifth, are incentives to unusual effort to make them outstanding anniversaries. Members can be confident that the efforts of the program committee will result in a meeting well worth attending, and also that their directors, officers and committees, with the voluntary and hearty co-operation of members, will make our fifth year a valuable contribution to progress in textile science.

The Stress-Strain Relation in Celanese Single Fibres

Control of Conditions for Reproducible Results

By RAYMOND L. STEINBERGER*

Abstract

In order to prove that the technique is capable of giving reproducible results the complete stress-strain relations for two nearly identical Celanese fibres have been obtained. The fibres differed somewhat in cross-section area. This introduces a difference in rate of stressing. A correction for this has been developed and applied. In the plastic region where pronounced shear slip is expected the stress-strain curve is found to be made up of a series of straight line segments, along any given one of which the strain hardening is proportional to the elongation. A change in rate of strain introduces errors which the simple Maxwell relaxation law cannot account for.

Introduction

IN the March, April and May (1934) numbers of TEXTILE RESEARCH, studies of the stress-strain relation in several types of single fibre were described. The results were obtained by a procedure such that conditions could be controlled with sufficient accuracy so that at least a descriptive differentiation between types of fibres may be made with confidence. If one wishes, however, to make a more accurate and quantitative study of the stress as a function of strain, of humidity, of rate of stressing, etc., it must be more fully demonstrated than has been done in the above-mentioned articles [1, 3, 7] that the variables may be measured and held at predetermined values with sufficient precision to give accurately reproducible results. With this as the principal object in view the following study was made.

* Dr. Steinberger is a Senior Fellow of the Textile Foundation working under the direction of Prof. P. W. Bridgman, Harvard University, Cambridge, Mass.

The stress-strain relations were determined for two nearly identical Celanese fibres, under known and nearly identical conditions.

Procedure

The apparatus and general method used in the determination of the stress-strain relations herein discussed have been described in detail in earlier numbers of TEXTILE RESEARCH.[1, 3, 7] From the same spool of Celanese yarn used for the hysteresis curves given in Ref.,[4] a 5 cm. length of yarn was cut. A number of single filaments were teased out and attached to paper tabs. Two were taken for the present tests, designated Test No. 1 and Test No. 2.

The specimens were mounted and sectioned by the method described.[4] In making the photo-micrographs the average value of the linear magnification was 925 ×. With the 0.85 N. A. objective used the maximum useful magnification was only 455 ×. In spite of the well-known objections to the increase of magnification beyond the bounds set by the limit of resolution of the objective, it was found advisable to increase the magnification to 925 × in order to get a section photograph which would be large enough to measure with sufficient precision. This is simply a matter of mechanical convenience. The 0.85 N. A. objective was used without a substage condenser. Under this condition the limit of resolution is 0.66 μ (microns) so that 0.66 μ is the smallest distance distinguishable with certainty in the measurement of diameters with the micrometer ocular. The maximum diameter (d) of each section (four for specimen No. 1 and three for No. 2) was determined with the calibrated micrometer ocular, each division of which was equivalent to 0.03 μ. The maximum diameter of the magnified image was also measured for each section. The ratio of the two diameters gives at once the linear magnification for each photograph. All section measurements were made with the fibre in the dry condition; that is, air of 0% R. H. was passed over the specimen for one hour before the measurements were made. The period of one hour had previously been shown to be sufficient for good drying.[6]

The factor of the greatest importance is the water vapor in the air surrounding the specimen during stressing. Both tests were carried out at very nearly the same R. H. The slight difference in R. H. between the two is due to a change in room temperature. As before, the sulfuric acid solution method[7] was used to obtain known water vapor pressures. The density of the acid solution was the same after the second run was completed as it was before the first run was started, namely 1.3051 g/cc. at 30° C. No difference in R. H. is therefore to be expected because of change in acid concentration during the two experiments. Since the density was accurately determined at one standard temperature, 30° C, the exact vapor pressure and R. H. can be computed for any value of room temperature from the tables given in Vol. III of the International Critical Tables. If the density is 1.3051 g/cc. at 30° C., one finds in the table on p. 56 (I. C. T.) that the composition of the solution is 41.11% acid by weight. The vapor pressure of the solution of this composition at the temperature of the run, say 19.9° C. for Run No. 1, is found in table p. 303 to be 9.49 m.m. hg. The vapor pressure of water at the same temperature is 17.43 m.m. hg. (table p. 212). The ratio of the vapor pressure of the solution

to that of the water is 0.5444 and the R. H. for Run No. 1 is 54.44%. For Run No. 2, which was made at 21.6° C, the R. H. is 55.00% or 0.56% higher than for Run No. 1.

Air is soluble in sulfuric acid solution, but in such a small degree as to cause an inappreciable error in density determination. This fact was established by leading air through a freshly prepared air-free solution of density 1.2771 (R. H. 60.7%). Extrapolation of the results for the solubility of air in H_2SO_4 solutions given in the I. C. T. leads to the same result.

In the present work, variations in room temperature influence the tensile properties in two ways: (1) through the effect on Relative Humidity just discussed; (2) and through the intrinsic effect on the strength and flow phenomena. The former is presumably much the larger and both are, at the present level of precision of the work, too small to warrant the considerable expense and trouble involved in providing accurate temperature control.

The method of stressing was the same as that already described,[2, 4] except for the following changes: As usual at the end of each 30 sec. relaxation period, tension and elongation were read and a new elongation increment was immediately applied. Since the same elongation increment (u_o) was applied to the specimen after the lapse of equal time intervals (Δ t) the fibre was, in effect, stressed with a constant rate of elongation for the duration of the experiment. The interval (u_o) was 0.05 m.m., while in earlier experiments it was twice as great. Initial lengths (L_o) were all approximately 15 m.m. The rate of straining (de/dt) in the present experiments was approximately 0.01% per second while in the earlier experiments it was 0.02% per second. In order to keep the rate of straining throughout one experiment constant and thus avoid the breaks observed in earlier stress-strain curves[3] (see Figs. 13 and 14), u_o was not changed during the given experiment. This results in a great number of observations; 81 for Run No. 1 and 88 for Run No. 2. In the interest of clearness many points are omitted from the curves of Fig. 1.

Results

The numerical details involved in the determination of section area are listed in Table I. Table II gives the conditions under which the two runs were made. The results are plotted in Figs. 1, 2, 3, 4. In Fig. 4, Run No. 1 is plotted (curve No. 1) for the sake of comparison with the results from three earlier runs:[4] (Figs. 10, 11, 12). Figs. 2 and 3 are plots of the upper or plastic part of the stress-strain curve drawn to a large scale in order to bring out details.

In previous stress-strain curves no corrections were made for the fact that the section area decreases with increasing elongation and unit stress computations were made on the basis of the initial area (a_o) under no stress. In solids, such as the metals and other structural materials obtainable in convenient size, the area shrinkage may be computed from Poisson's ratio (σ) which is the ratio of percentage change in diameter to percentage elongation. The determination of σ for a textile fibre would be exceedingly difficult because of the small diameter. For most solids σ lies between 0.2 and 0.5. At the upper limit the material is of such a character that the volume does not change during stretching. The lateral con-

TABLE I

Area of Cross-Section Measurements

Specimen No.	Section No.	Maximum Diameter: Of Specimen Section by Micrometer Ocular (Ave. of 4 readings)		Maximum Diameter: Of Image on Film by Scale and Dividers (Ave. of 2 readings)	Linear Magnification		Area Measurements: Planimeter Divisions (Ave. of 10 Traces)	Area: Computed from separate magnification	% Deviation from the average
		Ocular Divisions	μ	m.m.	X	% Deviation from Average		mm.²	
1	1	876.8	26.4	24.2	912	−3.1	10.94	2.78×10^{-4}	−1.0
	2	845.9	25.5	23.9	935	−0.6	11.19	2.72	−3.6
	3	846.6	25.5	24.2	947	+0.6	12.53	2.95	−4.4
	4	783.9	23.6	22.9	970	+3.1	12.56	2.83	+0.3
Averages			25.3		941			2.82	
							From one magnification		
2	2	850.3	25.6	23.4	909	− .87	12.61	3.10	−3.1
	3	869.4	26.2	24.4	929	+1.3	13.23	3.24	+ .93
	4	884.4	26.7	24.4	912	− .55	13.47	3.30	+2.8
Averages			26.2		917			3.21	

Micrometer ocular: one division..... 0.0302 μ
Planimeter: one division..... 21.17 m.m.²

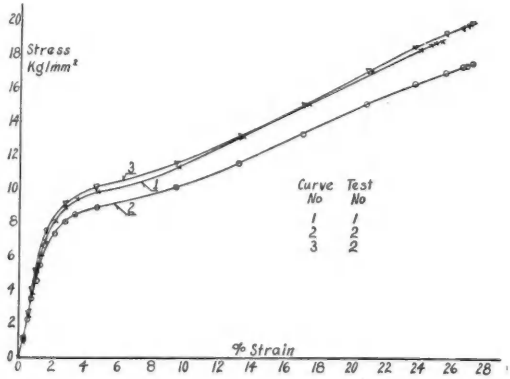

FIG. 1

TABLE II

Experimental Conditions

	Specimen No. 1 Run No. 1	Specimen No. 2 Run No. 2
Initial Section Area (a_0)	2.819×10^{-4} mm.^{2}	3.212×10^{-4} mm.^{2}
Tension Gauge Constant	0.565 g/cm.	0.577 g/cm.
Stress Constant	2.001	1.798
Room Temp. at Solution before Experiment	19.9° C.	21.6° C.
Room Temp. at Solution after Experiment	19.9° C.	22.2° C.
Average Room Temperature	19.9° C.	21.9° C.
Room Relative Humidity	45.2	62.4%
Acid Solution Density at 30° C.	1.3051	1.3051
Relative Humidity at Specimen. Average Room Temperature	54.44%	55.00%
Initial Length of Specimen L_0	15.4 mm.	15.6 mm.
Maximum diameter	25.3 μ	26.2 μ
Ratio of length to maximum diameter	609	596
Elongation Interval ΔL	0.05 mm.	0.05 mm.
Time of Stress Application Δt	30 sec.	30 sec.
Air Flow Rate	25 cc./min.	25 cc./min.
Duration of Experiment	41 min.	44 min.
Rate of Elongation or Strain Velocity	.011%/sec.	.011%/sec.

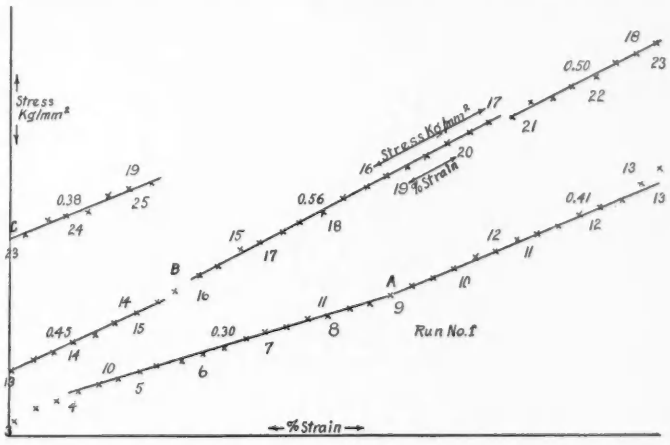

FIG. 2

TABLE III

Material	Poisson's Ratio	Material	Poisson's Ratio
Steel	0.269	Ebonite	0.389
Glass	0.245	Rubber	0.490
Copper	0.329	Paraffine	0.500
Lead	0.400	Gelatine	0.500

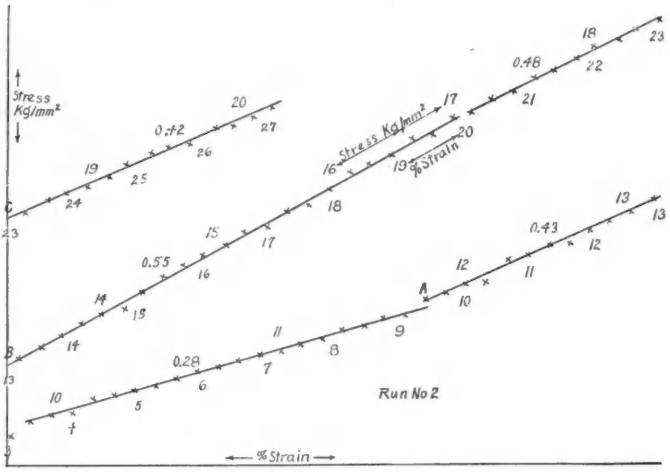

FIG. 3

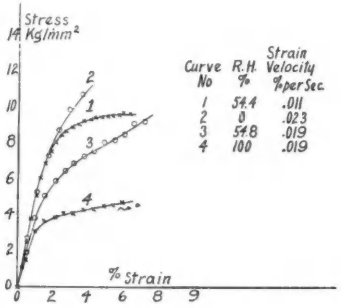

FIG. 4

traction is just sufficient to compensate for the elongation so that the volume does not change. If σ were greater than 0.5 a decrease in volume would take place. This is hardly possible in a simple tension experiment. Poisson's ratio increases[10] as the material becomes softer, as shown in Table III.

In the absence of definite experimental data it is reasonable to assume that the textile fibre materials may be classed with the soft bodies where $\sigma = \frac{1}{2}$, and that during the progress of a tensile test the total volume remains constant.

The volume of the fibre V is given by

$$V = La$$

where L is the length and a is the area of section. Then the total variation of volume with changes in L and a is given by

$$\delta V = a\delta L + L\delta a$$

and since the volume V is constant, δV is zero, and we have

$$\delta L/L = -\delta a/a$$

The percentage decrease in area is equal to the percentage increase in length. This condition however holds only when the changes are small. In the present case the elongation $\delta L/L$ amounts to nearly 28% and the equality does not hold very accurately. More precisely the volume V at any elongation is given by

$$V = (V_o + \delta V) = (L_o + \delta L)(a_o + \delta a)$$

where V_o, L_o, a_o are initial values when the strain is zero. Since the volume remains constant and $L_o a_o$ is the initial volume (V_o) the above expression reduces to

$$\delta a/a_o = -(1 + \delta a/a_o)\delta L/L_o$$

For the maximum elongation (28%), the use of the less exact expression leads to an error of about 7%. Solving the last expression for the area change we have

$$\delta a/a_o = -e/(1 + e) \qquad (1)$$

where e is the fractional or unit elongation ($\delta L/L_o$).

The actual stress is given by

$$s = T/a$$

where T is the tension, while the stress computed on the basis of the initial area is

$$s_o = T/a_o$$

With the tension T the same in both cases

$$s = s_o a_o/a$$

But

$$a = a_o(1 + \delta a/a_o)$$

which, combined with equation (1), leads to the result

$$a = a_o/(1 + e)$$

and the stress (s) may be written in terms of s_o

$$s = s_o(1 + e) \qquad (2)$$

Equation (2) involves no approximation and should hold for any value of e. In the curves of Figs. 1, 2, 3, 4, the true stress (s) has been plotted.

Discussion of Results

The object of the present experiments is to establish the fact that the technique gives reproducible results. The curves (1) and (2), Fig. 1, for the two runs, obviously do not coincide and at first sight the method is defective. An examination of Table II will make it clear that the conditions of experiment were so nearly identical that such a difference is improbable if the two fibres were identical in every way. The two specimens were selected in such a way that any difference in properties of the material would be very slight. There remain, therefore, only the geometric constants L_o and a_o. The difference due to L_o is small and is practically eliminated by expressing elongation results as percentages of the initial length. The only remaining quantity is a_o, which is considerably different in the two specimens. This means that the rate of stressing is considerably different. The same tension (T) imposed on the first fibre which has the smaller area of section will result in a considerably greater unit stress.

It is possible to apply a correction to the curve for Run No. 2, Fig. 1, raising it to position 3 which is in approximate coincidence with the curve for Run No. 1. If the fibre is a purely plastic body obeying Maxwell's simple relaxation law, certain expressions developed in the earlier study,[11] p. 281–283, should apply to the present case.

$$S = ku_o/a \text{ and } s_n = S\Sigma_n$$

The unit stress, S, is initially applied by giving the spring a sudden stretch u_o; s_n is the unit stress at the nth reading; k is the elastic constant of the spring and Σ_n is the sum of exponential terms involving the relaxation constant of the fibre-spring system.

$$\Sigma_n = (e^{-\Delta t/t_r'} + \ldots\ldots + e^{-n\Delta t/t_r'})$$

If a is the section area of the smaller fibre and $a + \Delta a$ is the section area of the larger, we have for the larger fibre

$$S' = ku_o/(a + \Delta a)$$

The ratio of the two initial stresses is then,

$$S/S' = (1 + \Delta a/a)$$

Then if we assume that the relaxation time (t_r') is the same for both fibres we have for any given value of n and a constant value of Δt:

$$s_n = s_n'(1 + \Delta a/a) \qquad (3)$$

Equation (3) is a relation between the unit stress (s_n') in the thicker

fibre and the stress s_n in the thinner fibre. Equation (3) has been used to raise the points of curve 2, Fig. 1, to position 3. The coincidence between curves 1 and 3 is sufficiently good to establish the main thesis of this report; namely that the method gives reproducible results.

Rate of Elongation

Sufficient data have been collected to make possible a comparison of rates of elongation. In Fig. 4 are plotted four curves: Nos. 2, 3, 4 are the initial branches of the curves given in Figs. 10, 11, 12.[4] Curve No. 1 is the same as No. 1 of Fig. 1 of this paper. In order to make comparison logical, equation (3) has been used to convert the rates of stressing to the standard fibre of Run No. 1. The areas and conversion factors are listed in Table IV.

TABLE IV

Curve No.	R. H. %	Section Area x 10^4mm^2 a	Δa	$(1+\Delta a/a)$	Temp. °C	Velocity Strain %/sec.	Initial Length L_o mm
1	54.4	2.819	0	1.00	19.9	.011	15.4
2	0	3.142	0.323	1.12	23.6	.023	14.4
3	54.8	3.301	0.482	1.17	21.4	.019	17.3
4	100	3.301	0.482	1.17	23.3	.019	17.9

Let us confine our attention to curves 1 and 3, which have been made under practically identical conditions except that in No. 1 the rate of strain is about half that of No. 3. Consider two points, one on each curve at the same value of strain. From Ref.[11] we have two equations:

$$E_n = nu_o - u_n$$

$$E_n' = n'u_o' - u_n'$$

where E_n is the total extension for s_n, the nth reading for curve No. 1 where the rate of straining is the smaller. The initially applied extension of the spring at the beginning of each time interval is u_o, and u_n is the residual deflection which measures the final tension at the end of the time interval Δt. The second equation refers to curve No. 3 where the rate of strain is smaller. Since the strains for the two chosen points are equal and initial lenghts are approximately equal E_n and E_n' are equal and also u_n and u_n' are small, compared with nu_o and $n'u_o'$ respectively.

$$nu_o = n'u_o'$$

But for curve No. 3 the initial extension u_o' is twice as large as u_o. Thus we have

$$n = 2n'$$

Also $S' = 2S$ because

$$S = ku_o/a \text{ and } S' = ku_o'/a$$

The stress at the n and n′ readings [9] in the two cases are

$$s_n = S\Sigma_n$$

$$s_n' = 2S\Sigma_n'$$

The two quantities Σ_n and Σ_n' are respectively the sums of two geometric series, one with n terms the other with n′ terms. Using this fact it is readily shown that the ratio of the stresses reduces to the value

$$s_n/s_n' = (1 + e^{-n'\theta})/2$$

where $\theta = \Delta t/t_r'$.

Therefore, according to the Maxwell relaxation equation, two curves, Nos. 1 and 3 of Fig. 4, should start at the origin where $e^{-n'\theta}$ is unity, then deviate more and more as n′ increases, the stress s_n' of curve No. 3 always being the larger. Below about 7% strain the reverse is the case with s_n the larger. The simple Maxwell relaxation equation therefore does not describe the facts completely.

In a subsequent paper the various theories of plasticity will be collected and critically discussed in an attempt to separate and measure the phenomena involved.

Plastic Flow

In the plastic region above about 4% strain there is pronounced shearing slip. The two curves, Nos. 1 and 3 of Fig. 1, have been plotted to a large scale in Figs. 2 and 3. The stress-strain relation is made up of a series of linear sections with distinct breaks between them. Over a given section, stress is proportional to strain. Considering the nature of the phenomena it is rather surprising that the length and slope of corresponding sections are even roughly equal for the two fibres. Since the stress increases proportionally to the strain the resistance to slip increases in the same manner. This phenomenon is strain hardening. Shear failure is typical of a body under a non-hydrostatic stress system when the difference ("stress difference") between maximum and minimum principal stresses is not zero. In simple tension the stress difference is just equal to s_n, the applied stress.

From simple geometric considerations [12] it can be shown that the shear stress is related to the longitudinal stress s_n by the formula

$$\tau = s_n(\sin 2\phi)/2$$

where ϕ is the angle of inclination of the plane, along which the shear acts, to the axis of the fibre. The shear stress varies from a maximum value of $s_n/2$ along planes inclined 45° to the axis of the fibre, to zero along planes either perpendicular or parallel to the axis. Shearing slip will thus set in first along 45° planes after a certain critical shear stress is attained. From the curves it is evident that the resistance to slip along the 45° planes increases proportionally to the strain, and finally attains such a value (stress value at A, Fig. 2 and Fig. 3) that slip begins along a set of planes less favorably situated; that is, along planes making angles slightly greater and slightly less than 45° with the axis. Slip resistance continues to increase linearly as before but now at a greater rate. After the stress

reaches the value at point B still another set of less favorably situated planes begins to slip. The resistance to slip is still a linear function of strain but increases at a still greater rate, because presumably all planes are still slipping. After point C, no new planes begin to slip but the slope begins to decrease. Presumably some planes have suffered so much slip that further increase of shear resistance ceases; *i.e.*, the shear resistance on a particular set of planes remains constant from this point on.

Each of the straight lines of Figs. 2 and 3 may be considered to be the sum of several straight lines. Let $M_1 \ldots . M_4$ represent the slopes of the lines as drawn. Let $m_1 \ldots . m_4$ represent the slopes of the constituent lines. Thus $M_1 = m_1$, $M_2 = m_1 + m_2$, etc. The various slopes are listed in Table V.

TABLE V

	Fig. 2	Fig. 3		Fig. 2	Fig. 3
M_1	.30	.28	m_1	.30	.28
M_2	.43	.43	m_2	.13	.15
M_3	.56	.55	m_3	.13	.12
M_4	.38	.42	m_4	.18	.13

The slope M_4 is less than M_3 by an amount which is roughly equal to either m_2 or m_3. Thus, either the m_2 or m_3 planes cease to support additional stress after point C is passed. Apparently the 45° planes support stress through the entire strain.

Conclusions

Two important conclusions can be drawn from this and the earlier reports.[1, 2, 7] One is that the methods outlined will give reproducible results. The other is that the complete stress-strain relation is an exceedingly complicated function, a direct attack on which cannot be very fruitful as far as yielding generally applicable constants or laws is concerned, until the various phenomena involved are defined, separated, and quantitatively measured in specially designed simple experiments.

With the statement that "the quantitative theory of plasticity is not yet far advanced" Jeffries[13] has given a classification and has defined each member of a group of characteristics some of which bear the familiar names, plasticity, strength, rigidity, elastic-after-work. All these characteristics enter into the stress-strain determination. For example, Jeffries defines the strength as that critical stress difference above which the rate of change of shape does not decrease with time of stress application.

The strength of a particular kind of fibre (say Celanese) could be determined by loading separately a series of fibres with weights so adjusted as to give uniformly increasing stress throughout the series. The fibres would extend at rates increasing with the applied stress. That stress at which the rate of extension does not decrease with time will be the strength of the fibre. Other simplified experiments should lead to quantitative data for the other properties.

As is characteristic in this field of investigation the "constants" depend somewhat on the sensitivity of the apparatus and on the patience of the observer. For example, in the determination of strength, the more

patient observer will take a longer period of time before deciding that the rate of extension does not decrease. The results have a disturbing element of subjectivity.

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"A Real Research Program"

BACK in February, 1926, the mythical "Jack Card," whose nom de plume allows free play in *Textile World* to a versatile imagination and a trenchant criticism, had the temerity to indulge in textile predictions which at that time seemed unlikely to win him a place among the prophets of old.

He recapitulates these seven predictions in the August number of *Textile World*, and although he does not claim that any of his predictions are "finished business," he does modestly claim, and justly, that substantial progress has been made on 85.72% (our figures) of them. One of his predictions (No. 6) was as follows:

"*Development of a National Textile Research Institute which may—or may not—overturn most of our fundamental ideas on textile manufacturing technique but which, at any rate, will let us know what's what.*"

"Jack Card's" comment on this is as follows:

"*I chortle with glee over the research item (6)—not because something monumental has been accomplished but because anything at all was done under the conditions of the last few years. In the U. S. Institute for Textile Research and the Textile Foundation, we have the makings of a real research program for the future.*"

The Microbiology of Textile Fibres

I. Cotton Fibre: Methods of Microbial Analysis*

By BRYCE PRINDLE†

Contamination

THE primary contamination of young cotton fibres may occur even before the bolls have opened. Insect punctures and the growth of molds are perhaps the principal cause of this early infection. A. von Holle [6] states that fungus infection takes place by penetration of the cuticle of young fibres. *Aspergillus niger* and *Rhizopus nigricans* [47] are frequently found growing on young bolls. It is probable, however, that most of the micro-organisms found in the ripe fibre are a result of contamination by dust and handling of the ripe fibre. *Aspergilli, Fusaria, Alternaria, Penicillia,* and members of genus *Rhizopus* have been found in baled raw cotton.[26]

Effect of Handling

Bearing its contamination from dust, infection, and handling, the fibre is baled and sent to the mill. Though it is there that much of the mildew trouble devleops, the effects of processing upon the contaminants has been little studied. Koutieichtchikof,[63] using the viability of *Aspergilli* as a criterion of the effect of processing, discovered that the mechanical processes had little effect and that the number of organisms surviving the processes of sizing and boiling-out as ordinarily practised was very great. The effect of adding food materials in the form of various sizes has been reviewed by Morris.[41]

Other than the fact that destruction of fabrics does occur by biological agencies, little is known of the microbiology of usage. The destruction of fish nets has been studied by the Bureau of Fisheries.[71] "Winter damage" of laundered goods, attributed to bacteria, is described by Allyn.[28] The effects of wet storage have been described by Fleming and Thaysen.[13, 14a]

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Growth upon Fibre and Associated Substances

The conditions under which mildew takes place are exactly those which would be expected to favor the activity of the organisms involved. Bacterial damage [33, 12] occurs principally in the presence of excess moisture. Mold growth [7] occurs in 8% to 20% of moisture and is favored by aerobic conditions.

The effects of microbial growth upon raw fibres have been studied and reviewed by many authors.[11, 14a, 17, 20, 23, 24, 29, 34, 42, 71, 72] Moisture is the most necessary factor for the starting of growth which seems to originate either in sizing material or in injured cotton hairs. The latter mode of infection has been exhaustively investigated by Denham.[17] The principal damage caused by growth of molds is staining of the fabric and production of areas which show up as spots of off-color in dyeing. Continued growth results in loss of fibre strength. Bacterial growth also results in tendering in the case of long exposure, but more subtle effects are indicated in some cases. Brittleness, resulting in production of "fly," has been attributed to bacterial growth.[23] Shrinkage and swelling of cotton fibres with increase in tensile strength, a process similar to mercerization, was noted by Trotman and Sutton,[24] but Thaysen and Bunker [42] were unable to confirm their results.

Identity of Organisms

Nearly all of the work just mentioned has dealt with the microbiology of spoilage. From time to time attempts have been made to identify the responsible organisms. An excellent summary of this literature is to be found in Thaysen and Bunker.[42] Since the date of the above mentioned publication, Galloway [65] has published a description of 180 varieties of mold isolated from spoiled fabrics. The occurrence of *Aspergilli* has been reviewed by Smith.[54]

Prevention of Mildew

Attempts to protect cotton materials against the growth of micro-organisms have followed two courses. Protection from dampness, wherever possible, is a sure preventative. Unfortunately, other means of protection must be had. The search for a suitable antiseptic has been long and difficult, as may be judged by the large number of patents and articles dealing with the subject.[14, 15, 16, 21, 22, 25, 27, 30, 32, 35, 36, 37, 40, 44, 45, 50, 53, 56, 58, 60, 61, 63, 64, 66, 69, 70, 74, 76, 78, 79, 80, 81]

Zinc chloride has long been the standard preventive for use in size, but it is a makeshift at best, because of its weight and undesirability in some fabrics. It is still, however, the standard of comparison. The knowledge of wood preservation has been borrowed and attempts to use many phenolic compounds have been made with little success. The knowledge that rare earth metals gave moth repellency was exploited, but their preventative effect is not as great against mildew. Copper bearing commpounds have been used with considerable success on fish nets but are too unsightly for clothing materials. The use of salicylates, borates and other common antiseptics has met with varying degrees of success. Lately, a more systematic

method of approach has been attemmpted by the organic chemist. The properties of various types of antiseptics have been combined to produce some very effective substances, whose use is limited only by their costliness. The microbiologists' approach to the problem is a much needed factor in the final solution, for not until the microbiology of the fibre is fully understood can the answer be sought in orderly fashion.

Testing Fibres and Fabrics

Mildew in cloth or fibre may be detected by direct observation under the microscope [31] or by similar observation after staining with lactophenol and cotton blue [62] or Pianese IIIb.[67] The viscosity of cellulose solutions prepared from the damaged material has been used as a criterion of spoilage. The swelling and staining of the fibres has also been studied.[59]

The resistance of fabrics or fibres to mildew is usually determined by strength tests after exposure to excessive moisture. Levine and Veitch [30] placed disks of material on agar plates and inoculated them with pure cultures of *Alternaria, Cladosporium* and *Mucor.* They compared the results obtained with the effects of weathering. Searle [57] tested the resistance of cloth samples to a mixed culture of soil organisms.

Experimental

Culture Media.—A comprehensive survey of the numbers and kinds of organisms associated with textile fibres involves the use of methods for studying the micro-flora of a large number of samples. The required methods must be economical of materials and time. They must also yield an accurate and comparable series of data when applied to samples of varying states of preservation. Unfortunately no such methods have been found recorded in the literature of textile microbiology.

Unlike many other substances of biological origin, textile fibres do not lend themselves readily to a study of their microbial content. The difficulties encountered are principally due to the complex structure of the fibre mass, and the fact that the entrapped micro-flora cannot be completely freed from its entanglement by mechanical disintegration or solution of the fibre without unduly injuring the microbes. The following studies have been carried out during the past year for the purpose of establishing methods of overcoming these difficulties. Raw cotton has been used in all the experimental work to date.

Samples from many sources have been collected. A few have been obtained directly from the mill. Many have been sent to the laboratory by mail. All samples of normal, dry, raw cotton are stored in glass, at room temperature, in a dark room. Two-quart glass preserving jars are very satisfactory for the preservation of samples, and all are placed in them as soon as received.

At the present time numerous samples of ripe, dry cotton bolls, baled raw cotton, and cotton from the roving frames are on hand. Most of these have been in storage for nearly a year and will be replaced by fresh samples for use in the counting and isolation of organisms.

Isolation.—The work of previous investigators deals to only a slight extent with the occurrence of microbes upon normal raw fibres. Hence a

few preliminary tests were conducted to obtain an indication as to the numbers and kinds of microbes present.

Small tufts of dry raw cotton were shaken with dilution waters and dilutions 1/100, 1/10,000, and 1/1,000,000 were prepared. One cubic-centimeter samples of each of the above dilutions were plated in duplicate Petri dishes, using as culture media synthetic malt extract agar (Difco) and Czapek's Soln. Agar. (Czapek's original formula.) One cubic-centimeter of each dilution was also inoculated onto the surface of plates of the media mentioned. In addition, tufts of the cotton were directly implanted into the agar media. Liquid media were also used, but found to be unadaptable to the present investigation.

The inoculated media were incubated at 20° C. in the dark.

Those inoculated with washings of the fibre showed little growth, but a very interesting picture was obtained from the media into which the cotton fibre had been directly placed. An abundant growth, principally molds, was seen about the periphery of each cotton tuft. This was evidence of a considerable contamination of the fibre and demonstrated the presence of several different kinds of organisms.

As a result of this preliminary test, several valuable suggestions were obtained for use in later work. It was evident that dispersal of the organisms of the fibre cannot be obtained without simultaneous disintegration of the fibre. Several types of media must be used in order to support the growth of various types of organisms. Standard conditions of incubation should be used.

Incubation.—An incubator was constructed and regulated to a temperature of 25° C. $\pm$ ½° C. The relative humidity maintained by circulating the enclosed air over water remains at 75–80%.

Culture Media.—The choice of culture media to be used in studying cotton contaminants was made with several points in mind:

1. It is desirable to use standardized media so far as possible in order to facilitate duplication of the work.

2. The media must be efficient; that is, they must support the growth of a varied flora in order to get a maximum of cultures with few media.

3. They should lend themselves to the special study of the cotton fibre and later to a comparative study of the flora of this fibre and that of another.

The first condition was fulfilled by limiting the choice of media to: (A) The original cotton sample or extracts of it. (B) Synthetic media, or media prepared by makers of standardized culture media. The following media were chosen and have been used up to the present with only one alteration, a change in the pH of Czapek's Soln. Agar:

"Synthetic Malt Agar" (Digestive Ferments Company)
(pH = 4.5)

Technical Maltose (Difco)	12.75	grams
Dextrine	2.75	
Glycerin (C.P.)	2.35	
Bacto Peptone	0.78	
Bacto Agar	15.00	
Water (distilled)	1000	cc.

"Nutrient Agar" (Digestive Ferments Company)
(pH = 6.7)

Bacto-Beef Extract	3 grams
Bacto—Peptone	5 grams
Bacto—Agar	15 grams
Water (distilled)	1000 cc.

Czapek's Soln. Agar (Original)
(pH = 7.0)

$NaNO_3$	3.00 gm.	$FeSO_4$	0.01 gm.
K_2HPO_4	1.00 gm.	Sucrose	30.0 gm.
$MgSO_4$	0.50 gm.	H_2O	1000 cc.
K Cl	0.50 gm.	"Bacto" agar (Digestive Ferments Co.)	15.00 cc.

The original plan was that the nutrient agar should support the growth of most of the bacteria present; the Czapek's Agar should serve similarly for the molds, and the malt agar was to serve as a means of obtaining cultures of the yeasts and other carbohydrate-loving organisms. A revision was necessary, however, in view of the fact that cotton fibre contains so many bacteria capable of growing upon Czapek's Soln. Agar that the mold colonies on the same were completely obscured.

Pasteurization of the inoculum, incubation at low temperatures, or control of the pH of the medium were considered as means of eliminating the excessive bacterial growth. pH control was chosen in preference to the other methods, because it offers little chance of injury to the microbes in question and it does not appreciably slow up the development of colonies.

Hence a series of studies were made upon the effect of adding varied amounts of 0.1N HNO_3 to Czapek's Soln. Agar of the above mentioned composition. Acid was added after sterilization, because of softening of the agar jelly by hydrolysis under steam sterilization at pH less than 4.5. The quinhydrone electrode was used in composing titration curves showing the variation of the pH of the medium upon the addition of acid. (See Fig. 1.)

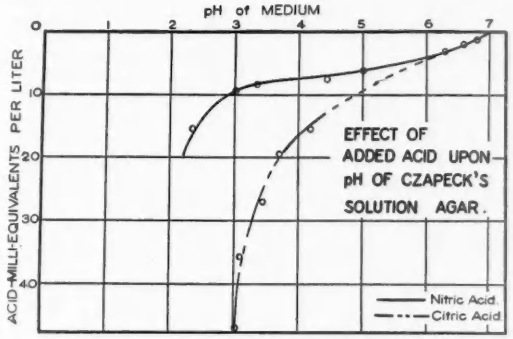

FIG. 1

The above titration proved that nitric acid was not suited to the control of the pH of Czapek's Soln. Agar because of its low buffering power. An organic acid seemed desirable as a source of the needed buffering power, and a study of the variation of the pH of the medium with additions of citric acid was made. Fig. 1 clearly shows that the desired accuracy of pH control is easily obtainable with this acid.

Having determined the action of nitric and citric acids upon Czapek's Soln. Agar, the growth of cotton fibre microbes upon the acidified medium was studied. The results of the plating experiments are shown in Tables III and IV.

The technique used was the following:

1. A piece of raw cotton was finely cut up with scissors.
2. The finely divided cotton was violently shaken with distilled water.
3. The resulting suspension of debris in distilled water was plated out in a series of dilutions from 1/100 to 1/1,000,000 on the prepared agar, in Petri dishes.

Table III

Acidity	Dilution	Counts on Acidified Czapek's Solution Agar Date of inoculation - Jan. 24, 1933. Jan. 25, 1933 . Jan. 26, 1933 . Jan. 27, 1933 . Jan. 28, 1933											
pH		B	M	B	M	B	M	B	M	B	M	B	M
7.30	2	309	0	315	0	x	8	x	9	x 14		x 10	
	4	3	0	2	0		0		0	0		0	
6.40	2	312	0	x	0	x	10	x	8	x 13		x 11	
	4	2	0	2	0		0		0	0		0	
5.90	2	268	0	291	0	x	9	x	9	x 13		x 12	
	4	1	0	3	0		1		1	1		1	
5.70	2	226	0	238	0	x	4	x	9	x 13		x 13	
	4	3	0	2	0		0		0	0		0	
5.30	2	203	0	254	0	x	8	x	7	x 12		x 12	
	4	1	0	0	0		0		0	0		0	
4.18	2	7	0	6	0	10	10	11	8	12	11	11	10
	4	2	0	1	0	2	1	1	0	2	1	1	1
3.84	2	0	1	3	1	1	10	2	7	1	10	2	7
	4	1	0	0	0	1	0	0	0	1	0	0	0
3.33	2	1	1	0	1	1	5	1	3	2	6	1	4
	4	2	0	1	0	2	0	1	0	2	0	1	0
3.00	2												
	4												

												12	13
												2	1
												1	11
												1	0
												2	6
												2	0
0	7	1	9										
0	0	0	1										

x- More than 300 bacterial colonies on plate.
B- Bacteria M- Molds

4. After several days incubation at 25° C. the numbers of molds and bacteria developing on each agar plate, and the condition of the agar and developing colonies, were recorded.

Table III shows clearly the result of inoculating the Czapek's acidified agar with HNO_3. All the plates for this experiment were inoculated with an equal amount of material from a single cotton sample. Two series of counts were made. Between pH 5.3 and pH 7.3, the bacteria grew so profusely as to obscure the mold colonies in three days. At pH 4.18, however, there was little activity on the part of the bacteria. Mold growth shows no inhibition at this acid concentration. Below pH 3.84 growth of all forms was diminished and difficulty was experienced in preventing excessive hydrolysis of the agar jelly.

Table IV

Comparison of Growth on Czapek's Agar Acidified With Nitric and Citric Acid

Nitric Acid

pH		Counts		
7.00	Many bacteria and molds, count obscured.			
4.70	Similar to pH 7.00			
3.90	Few bacteria. Molds -	Dil. 1	190	125
		Dil. 2	22	18
		Dil. 3	3	0
3.55	1 or 2 bacteria. Molds-	Dil. 2	22	14
		Dil. 3	4	2

Citric Acid

pH		Counts		
3.07	No bacteria. Molds -	Dil. 2	20	23
		Dil. 3	2	1

After having determined, approximately, the pH range needed for exclusion of bacterial growth, more detailed work was done using citric acid as well as nitric acid. Growth on Czapek's agar acidified with either acid was compared with the other. The results are tabulated in Table IV. The results of the previous experiment using nitric acid were confirmed. A favorable growth was obtained at pH 3.90. A count which was nearly identical was obtained in the cultures acidified with citric acid and the appearance of the mold colonies was the same to the naked eye. The only

apparent difference was a slightly slower rate of growth. Citric acid is therefore quite suitable for this use, in that it does not inhibit mold growth and a medium of high buffering power is possible.

Further experiments were conducted with the citric acid. A series of plate counts using varying acidities showed that a medium adjusted to pH 4.20 allowed only a few bacterial colonies to develop and did not interfere with the development of molds except to slightly decrease the rate of growth.

At this point in the research an unaccounted-for variation in the pH of successive batches of Czapek's Soln. Agar, containing equal amounts of all constituents, was noted. A brief investigation established the cause of this variation. It was due to the fact that, upon heating the agar medium containing sufficient citric acid to lower the pH to about 4.0 there was a very considerable increase in the active H^+ ion content of the medium. Hence, if the medium were steam sterilized at 15 pounds for 20 minutes, allowed to harden, and then remelted at 100° C. for plating, the initial pH adjustment was valueless. In view of these experimental results the following procedure was developed for producing a Czapek's Soln. Agar which, when poured into Petri dishes and hardened, is at pH 4.20 $\pm$ 0.3:

A.	$NaNO_3$	3.00 gm.	Sucrose	30.0 gm.
	K_2HPO_3	1.00 gm.	"Baeto" agar	15.0 gm.
	$MgSO_4$	0.50 gm.	H_2O (distilled)	900 ml.
	K Cl	0.50 gm.		
	$FeSO_4$	0.01 gm.		
B.	Citric Acid			1.00 gm.
	H_2O			100 ml.

Solutions A and B are sterilized at 15 pounds for 20 minutes in steam. Before the agar hardens they are mixed aseptically and the mixture is bottled aseptically and allowed to harden. Just before pouring plates the required amount of medium is quickly melted in boiling water, and cooled by dilution of the hotwater bath to about 45° C.

The media just noted, nutrient agar, synthetic malt extract agar, and Czapek's Soln. Agar acidified with citric acid will be used for the major part of the counting work in this survey. Special media will be developed from time to time as the need arises.

Separation of Organisms from Fibre

The preliminary cultures just described established beyond a doubt the fact that the contamination of the cotton fibre of commerce was far too great to be studied by growth of the organisms directly upon the fibre. It was also obvious that the fibre could not be dispersed in water for purposes of making dilutions without destroying most of the life upon it.

Separation of many different organisms from the fibre is not difficult but to do so quantitatively is a problem. It was felt that the knowledge of the frequency of occurrence of different types of microbes upon the cotton fibre, and upon other fibres, was of such great importance that considerable time was spent in working out a standard method of counting them. The two processes of counting and isolation of pure cultures are combined in the final scheme.

For purposes of developing technique one-gram samples (approximately) of raw cotton have been used.

A plan was devised by which the procedure for counting organisms from a one-gram sample was as follows:

1. Sample cut up into sterile weighing bottle, using shears and tongs which had been sterilized by soaking in 95% ethyl alcohol, and consequently burning off the alcohol.

2. Sample weighed, adjusted to near one gram, added to 99 cc. of sterile distilled water and violently shaken by hand.

3. 1-cubic-centimeter samples for diluting and plating drawn from the bottle containing a mixture of water and cotton.

This technique was tested with a sample of sterilized cotton to determine the degree of contamination involved. The results (Table V) indi-

Table V

Test of Counting Technique

Inoculation- June 15, 1932. Incubation at 25°C.			
Sample	Dilution	June 16, 1932.	June 17, 1932.
		Synthetic Malt Extract Agar	
1	2	0	0
	4	0	0
2	2	0	1 mold
	4	0	0
3	2	1 mold	0
	4	0	0
4	2	0	0
	4	0	1 mold
		Nutrient Agar	
1	2	0	1 mold
	4	1 mold	1 bacterium
2	2	0	0
	4	0	0
3	2	0	0
	4	0	0
4	2	0	0
	4	0	0

cate that it is not serious as far as counting is concerned. It amounts to slightly more than 1% of the total count if the lowest acceptable plate count is 30 colonies per plate.

The same procedure was used in counting the number of organisms

upon two samples of raw cotton. The results are tabulated in Table VI showing total numbers of organisms of all kinds. The experiment was repeated and the results tabulated in Table VII.

Table VI

Plate Counts

Incubation- 2 days at 25° C.							
Sample	Dilution	Czapek's		Nutrient		Syn. Malt	
A 1.59 grams	2	x	x	x	x	x	x
	3	120	71	640	700	1000	800
	4	0	6	216	117	92	67
	5	0	0	14	19	12	11
	6	0	0	3	4	0	1
B 1.51 grams	2	x	x	x	x	x	x
	3	800	560	x	x	x	x
	4	12	x	420	700	257	340
	5	14	6	46	56	27	33
	6	1	0	4	7	1	2

x- Too many colonies on plate for counting.

Many more bacteria were found than molds, but large discrepancies occurred in the counts. It may be seen by a brief inspection of the charts that counts of duplicate plates do not agree and 1: 10 or 1: 100 dilutions do not show counts that bear the proper relationships to lower dilutions. Much of this error is probably due to the great numbers of organisms occurring on some plates. Because of this only counts between 30 and 300 colonies per plate are to be considered significant in the future.

In an effort to discover other causes of so great an error, many duplicate plates were made from one sample. They did not check any better in spite of the fact that sample size was carefully regulated to 1.02 grams. Table VIII contains the data of this experiment.

The idea of separating all of the contaminating organisms from the cotton fibre was definitely abandoned at this point, and the alternative of separating a definite portion of them by the use of a standard procedure

was developed. Samples were forced through a sterile glass cutting tube, 13 mm. in diameter. As the cotton emerged from the end of the tube, it was cut off with shears into a weighing bottle. After weighing it was shaken up with distilled water by hand and a 25 cc. portion of supernatant liquid was poured off. Duplicate plates were poured from this. Table IX shows that the counts obtained are at least of the same order of magnitude for duplicate plates, and the dilutions are nearly correct although the number of organisms present is really too small to have great significance.

Table VII

Counts on Raw Cotton

		Incubation at 25°C.					
Sample	Dil-ution	Czapek's		Syn. Malt		Nutrient	
	Day+	2	3	2	3	2	3
A.	2	-	-	-	-	-	-
		-	-	-	-	-	-
	3	120	172	1000	-	640	-
		71	175	800	-	700	-
	4	0	22	92	100	218	172
		6	8	67	38	117	170
	5	0	0	12	16	14	33
		0	0	11	3	19	29
	6	0	1	0	0	3	5
		0	0	1	3	4	7
B.	2	-	-	-	-	-	-
		-	-	-	-	-	-
	3	800	-	-	-	-	-
		560	-	-	-	-	-
	4	12	24	257	260	420	400
		-	68	340	225	700	650
	5	14	38	27	34	46	48
		6	15	33	37	56	84
	6	1	2	6	6	8	10
		0	1	2	4	7	6

- Too many colonies on plate for counting.

Shaking by hand was eliminated as a possible source of variations by the use of a machine. At the time of the test, for which the data are recorded in Table X, the machine shook samples horizontally. Since then it has been altered to shake vertically in the arc of a circle of radius 14.0 cm. (to center of shaking support). The frequency of the vibration is 500 per minute and the amplitude 2.7 cm.

Four samples of about equal weight and from the same sample of cotton fibre were prepared with the cutting tube and shaken on the machine for varied lengths of time. Another sample was shaker by hand for comparison.

The machine-shaken samples show a far greater uniformity of count than does the hand-shaken one. A greater number of organisms is also

Table VIII

Effect of Long Incubation

Incubation at 25°C. Medium- Nutrient agar.									
Dil-ution	Day→	4		5		Dil-ution	Day→	4	5
3	No. 1	248	246	-	-	5	No. 1	3 2	4 2
	2	260	-	294	-		2	1 0	3 0
	3	205	246	297	268		3	3 2	3 3
	4	-	-	-	-		4	2 1	3 2
	5	-	-	-	-		5	5 4	10 9
	6	-	-	-	-		6	2 1	2 1
	7	-	-	-	-		7	8 9	12 14
	8	266	265	264	297		8	3 8	5 10
	9	261	217	-	-		9	3 1	4 2
	10	-	-	-	-		10	14 20	25 31
4	1	28	32	43	50	6	1	0 0	0 0
	2	24	24	36	32		2	0 1	0 1
	3	43	28	55	42		3	1 0	1 0
	4	97	75	111	82		4	2 1	2 1
	5	144	133	164	171		5	3 1	3 1
	6	48	35	48	50		6	1 0	1 1
	7	193	141	198	165		7	1 0	1 0
	8	60	41	76	46		8	0 0	0 1
	9	24	39	41	50		9	0 0	1 0
	10	253	274	-	-		10	4 0	7 4

- Too many colonies on plate for counting.

obtained. According to the figures it appears that 3-minute shaking removes the largest number of organisms without injury, but this conclusion is not warranted because of the small-size sample used and the fact that only one test was made. The longer shaking may have destroyed some forms but it may also have freed others closely associated with the fibre.

The advantage of standard shaking was proven, but it may not be that all of the types of microbes were represented in the liquid drawn off after shaking. The effect of adding sand to help in tearing up the fibre was tried. Sand, washed and graded between 12 and 20 mesh, was used. The turbidity was observed after shaking the fibres, which had been cut up in the usual manner, for five minutes (selected as maximum time for shaking). More turbidity was noticed when sand was used and the cotton appeared torn and ragged. Soaking in water at 0° C. for 1 hour before shaking caused no increase in the resulting turbidity. Some heavy glass was then broken up, sized to between 4- and 12-mesh, and the cotton samples were

shaken with it. A very great turbidity was obtained. Much of this was due to small bits of cotton fibre floating about in the liquid. It seemed highly desirable that these bits of cotton should be available so that they might be imbedded with their adhering microbes in the agar medium. Shaking

Table IX

Incubation at 25° C.					Medium- Nutrient agar					
Dilution	Day→	3	Dilution	Day→	3		4		5	
2	No. A	-	4	No. 1	63	79	77	102	80	118
	B	-		2	65	54	69	79	72	68
	C	-		3	50	58		76		75
	D	-		4	58	42	61	44	74	42
	E	-		5	81	61	86	69	81	70
	F	-		6	34	55	49	69	89	76
	G	-		7	63	69	64	71	76	71
	H	-		8	62	66	78	67	83	71
	I	-		9	79	63	76	63	86	66
	J	-		10	64	64	64	69	64	73
3	1	-	5	1	1	8	2	9	2	9
	2	-		2	2	3	2	5	3	5
	3	-		3	3	5	6	6	8	7
	4	-		4	5	7	7	8	9	8
	5	-		5	5	6	5	7	7	7
	6	-		6	4	9	7	9	7	9
	7	-		7	2	2	2	3	2	5
	8	-		8	5	2	6	3	6	6
	9	-		9	7	8	7	9	8	9
	10	-		10	4	3	5	4	5	5

for five minutes with 4–12 mesh broken glass was accepted as a standard procedure.

All of this data and information has been used in formulating a standard method for preparing cultures from raw fibre samples, which, when applied to a large number of samples, should give an accurate index of the number and a rough picture of the kinds of micro-organisms present. The data are comparable for one kind of fibre. The finished plan of analysis is presented in the form of a chart. (See Fig. 2.)

Methods of Isolation of Pure Cultures

Pure cultures of organisms for identification are picked directly from the various media used for counting. As a rule, pure cultures may be picked from the colonies with the naked eye. Cultures of both molds and

Table X

Effect of Shaking on Counts

Sample No.	Weight
1	1.29 grams
2	1.27 grams
3	1.23 grams
4	1.33 grams

Incubation at 25°C. Medium- Nutrient agar.

Shaking	Dilution	Days 3	Days 4	Shaking	Dilution	Days 3	Days 4
1. By hand	3	-	-	3. By machine 3 min.	3	-	-
	3	-	-		3	-	-
	4	93	104		4	114	174
	4	79	84		4	105	180
	5	10	11		5	14	21
	5	12	14		5	10	15
2. By machine 1 minute	3	-	-	4. By Machine 5 min.	3	-	-
	3	-	-		3	-	-
	4	62	138		4	95	130
	4	66	130		4	103	131
	5	3	8		5	9	14
	5	7	14		5	9	14

Corrected counts: (Figures for dilution 4 used)

1. 740,000/ gram
2. 1,050,000/ "
3. 1,450,000/ gram
4. 1,000,000/ "

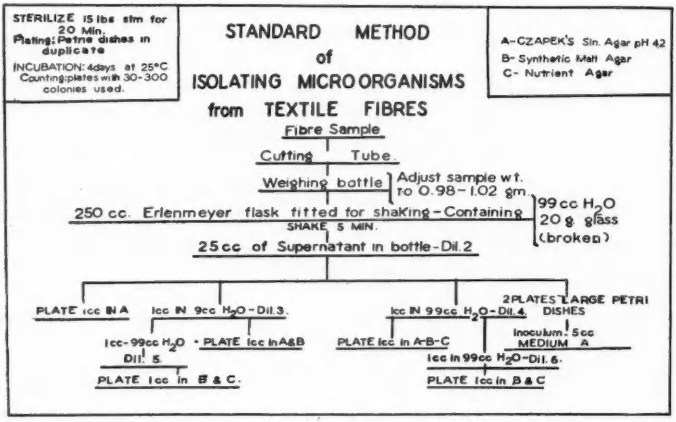
STERILIZE 15 lbs stm for 20 Min.
Plating: Petrie dishes in duplicate
INCUBATION: 4days at 25°C
Counting: plates with 30-300 colonies used.
STANDARD METHOD of ISOLATING MICRO ORGANISMS from TEXTILE FIBRES
A-CZAPEK'S Sln. Agar pH 4.2
B- Synthetic Malt Agar
C- Nutrient Agar
Fibre Sample
Cutting
Tube
Weighing bottle
Adjust sample wt. to 0.98-1.02 gm
250 cc. Erlenmeyer flask fitted for shaking - Containing
99 cc H_2O
20 g glass (broken)
SHAKE 5 MIN.
25 cc of Supernatant in bottle-Dil. 2
PLATE 1cc IN A
1cc IN 9cc H_2O-Dil. 3.
1cc-99cc H_2O Dil. 5
PLATE 1cc in A&B
PLATE 1cc in B & C.
1cc IN 99cc H_2O-Dil. 4.
2 PLATES LARGE PETRI DISHES
Inoculum - 5cc MEDIUM A
PLATE 1cc in A-B-C
1cc in 99cc H_2O-Dil. 6.
PLATE 1cc in B & C

FIG. 2

bacteria so chosen are inoculated by a combination streak and stab method into agar slants of the same composition as the medium upon which the colony originated. An effort is made to obtain as many distinct types as possible without duplication. The frequency of occurrence of the various types is also noted. When the original culture is flourishing an attempt is made to get all bacteria to grow on nutrient agar and all molds on malt extract agar.

Pure strains of bacteria are readily obtainable in this way, but cultures of molds are quite commonly composed of two or more separate strains, species, or more distantly related types. A suspension of spores from the mixed culture is prepared. This is then plated out in Petri dishes. When sufficient development has taken place a micro-manipulator in the form of a sharp nichrome needle is used to pick out single spores or spore heads under the dissecting microscope. Many types of moulds have been successfully obtained in pure culture by this simple procedure. (Thom and Church.—"The *Aspergilli.*")

Beyond the formulation of methods for studying the micro-flora of cotton fibre, several interesting and suggestive experimental facts have come to light. Foremost of these is the discovery of a very large contamination in the ordinary raw fibre. Counts obtained during the course of development of methods indicated the presence of 500,000 to 2,000,000 bacteria and 1,000 to 5,000 molds upon a one gram sample.

The large number of molds represented is in itself a warning against any carelessness in exposing the fibre to excessive moisture. A few species of mold are present consistently and in predominating numbers, suggesting that they may have grown upon the fibre at some time. Others are usually present but in small numbers. They are probably contaminants typical of some method of treating the raw cotton, or from some characteristic environmental source.

The number of bacteria found is somewhat surprising, and suggests that perhaps the possibilities of bacterial growth have been somewhat neglected in studying the more obvious mold growth. Trotman and Sutton [24] have sounded the keynote of a suggestion in regard to the growth of bacteria associated with cotton fibre in their paper on the effects of *B. subtilis* and *B. mesentericus.* Though the direct effects of bacterial activity upon cellulose may have no importance from a textile standpoint, the indirect effect may be made to yield valuable information upon further study.

A few days' incubation of raw cotton fibre in distilled water is sufficient to give rise to a very swift growth of bacteria. A distinct odor is produced, which suggests that the protein materials of the fibre are quickly fermented in the presence of excess moisture.

The variety of organisms to be found in a gram-sample varies considerably according to the sample. In one attempt 11 distinct types of bacteria and 12 kinds of molds were picked from plates made from a single sample having a bacterial count of 2,000,000/gram and a mold count of 600,000/ gram. One type of pink mold predominated in these counts suggesting that it had previously grown upon the fibre.

References

For references see The Microbiology of Textile Fibres. Bryce Prindle. *Tex. Rsch., IV,* 9, 413–28; *IV,* 10, 463–78 (1934).

Combing Tests with Individual Wool Fleeces

Indicate That Spinning Value May Not Be Predictable from Single- or Group-Fibre Measurements

By J. F. WILSON *

Introduction

The methods of measuring results of research into the problems of wool production have been largely restricted to measurements of the physical and chemical attributes of the single fibre. It has been customary to measure the fineness of wool by taking a mean of the diameters of single fibres, and to observe the length, breaking strength, and stretch by repeated operations on single fibres. Measurements of the fleece as a unit have been almost confined to recording greasy and clean weights.

The experiment described in this paper was conducted in the hope of finding a new expression of results relating to the entire fleece which might be used in biological investigations of wool. It is published more as a record of results than an attempt to prove that the objective was reached. Combing tests on individual fleeces have not been reported previously.

The results of the test indicate that it is not an easy problem to take a sufficient number of single fibre measurements to yield data in harmony with those obtained from the fleece as a whole. Several biologists have considered that the measurement of 100 fibres is sufficient to determine the mean diameter with satisfactory accuracy. The textile processes, however, involve the manipulation and study of fibres en masse, largely by rule-of-thumb methods. The results of the two methods of approach are not easily comparable.

It is conceivable that the behavior of wool in some textile processes is not predictable from customary measurements of single fibres. Krais[1] *has shown that*

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two wools of similar fineness, breaking load and extension at break may vary considerably in their adaptability for manufacturing purposes. Whether such differences should be studied from the standpoint of the individual fibre, the fleece as a whole, or a combination of the two, as was done in this experiment, remains for the future to disclose.

Summary

THIS paper is a record of results obtained from combing individual fleeces of wool. Eleven fleeces from fine wool ewes of comparable ages, and six fleeces from fine wool rams, all produced on essentially the same plane of nutrition were used in Group I. The combing test showed substantial differences in the percentage of noil and the character of the top.

Measurement of the midsection diameters of a total of 200 fibres from each fleece (50 from the shoulder, 50 from the thigh and 100 from the combed top) showed that either this number is inadequate or the percentage of noil is not necessarily closely related to fibre fineness.

Measurement of the breaking load of 200 single fibres and 20 samples of "yarn," each made from 20 fibres, indicated a general tendency of the breaking stress to be reflected in the percentage of noil.

Large differences in the yield and in the percentage of grease present in the fleeces were noted and serve to show that such variations may exist even among sheep of the same breed kept in the same environment.

In this test, fleeces with a comparatively high grease content, and fleeces showing exceptionally well defined crimp tended toward a higher percentage of noil, although the relationship was not strong.

The length of the staple as measured by shoulder and thigh samples, and the sex of the animal seemed unrelated to the percentage of noil.

The characteristic of the top was apparently not greatly affected by the percentage of grease, the percentage of noil, the definition of the crimp, nor by the sex of the animal.

Group II consisted of Romney wether fleeces produced under various controlled planes of nutrition and combed individually.

The percentage of noils was lower for the fleeces grown on a maintenance diet than for those produced by the same animals on a supermaintenance diet. Measurement of the diameter and breaking load of 200 single fibres, and determination of the breaking load of 20 samples of "yarn" from each fleece offered only a partial explanation of the behavior of the fleeces in combing. Similar measurements of the fleeces produced on a submaintenance ration provided a satisfactory explanation of the percentage of noils obtained.

The characteristics of the top from the supermaintenance and maintenance diets were on the whole similar, but the top from the submaintenance fleeces was definitely inferior.

The experiment points out the necessity of measuring a large number of fibres in order to secure data representative of the fleece as a whole, and indicates the possibility that the behavior of the fleece in processing may not be predictable by measurements of single fibres.

Experimental

GROUP I.—Combing test on fine wool fleeces of sheep on the same plane of nutrition.

ELEVEN fleeces from young ewes and six fleeces from breeding rams were selected at shearing time from a superior flock of range sheep in northern California. This flock was established about 50 years ago and consists of Rambouillet sheep of practically pure breeding.

Each of the ewe fleeces was taken from a ewe, known by a system of ear notching to be not less than two nor more than three years old. Each ewe which furnished a fleece for the experiment was raising a lamb at the time of shearing and all of the ewe fleeces were taken from animals which had spent the entire 12 months' growth period of the fleece in the same pasture under conditions practically identical. Thus, breed, age, and nutritional regimen are minimized as variables in interpreting the data.

The six ram fleeces were taken from animals each of which had been bred to approximately 50 ewes during the previous breeding season. They had not been turned in with the same bands of females during this time and, since some variation is found in the quality of forage in different pastures of the 4000 acre ranch, the rams may not have been on the same plane of nutrition during the breeding season. Previous to and subsequent to that time, however, all of them were kept together, and were maintained in good condition at all times.

The ewe fleeces were selected on four points: (*a*) high grease content, (*b*) low grease content, (*c*) well defined crimp, (*d*) poorly defined crimp. The ram fleeces were selected simply for comparison with those from ewes.

The wool was brought to the wool laboratory at the University of

California, sampled for grease analysis and scoured. In sampling the fleeces were spread out on a large table and approximately 40 small locks were withdrawn from all parts of the fleece. Combined, they constituted the sample for ether extraction. Duplicates were taken.

The scouring was done by the method described in a previous paper.[2] Lots of about 200 grams were scoured and the operation repeated until the entire fleece had been cleaned. Stained portions, short wool from the shanks, burry and seedy bits were sorted out, scoured separately and discarded. These portions were considered, therefore, in arriving at the clean weight of the fleece but did not enter the subsequent processes. The proportion of off-sorts was variable among the different fleeces, a fact which accounts for the discrepancies between the clean fleece weights shown in Table 1 and the combined weights of top and total noil shown in Table 3.

TABLE 1

Sheep No.	Grease wt. of fleece	Scoured wt. of fleece	Yield	Grease	Dirt and suint	Crimp*
Ewe	Grams	Grams	Per cent	Per cent	Per cent	
3	2905	1599	55.0	33.27	11.73	Good
4	2824	1349	47.8	33.19	19.01	Exceptional
5	2871	1614	57.2	27.44	15.36	Exceptional
7	3342	1586	47.4	32.95	19.65	Good
9	2841	1757	61.8	22.41	15.79	Poor
11	4363	1831	42.0	35.75	22.25	Good
12	4301	2120	49.3	30.90	19.80	Exceptional
13	3610	1529	42.5	38.18	19.32	Exceptional
15	2715	1496	55.1	23.37	21.53	Poor
18	2548	1690	66.3	14.71	18.99	Poor
19	3038	1834	60.1	17.46	22.44	Poor
Ram						
A	5023	2006	39.9	30.35	29.75	Poor
B 312	5271	2349	44.6	37.92	17.48	Good
C 227	5091	1906	37.4	38.99	23.61	Good
D 45	4583	2041	44.5	28.55	26.95	Good
E 205	6183	2557	41.4	44.41	14.19	Exceptional
F 226	4881	2046	41.9	39.21	18.89	Good

*Description refers to the accentuation of the crimp not to the number of crimps per inch of fiber length.

Table 1 shows the greasy and clean weights, the percentage of grease, and the yield of each fleece. The variations in the yield of the fleeces seem large, but are no greater than have been found among other flocks of fine wool sheep in the western states.[3, 4]

An indication of the fineness of the fleece was obtained by measuring the midsection diameters of 200 fibres with a micrometer. Fifty of these fibres were taken from the shoulder, 50 from the thigh, and the remaining 100 from the combed top, representing all parts of the fleece.

The relative strength of each fleece was determined by observing the breaking load of each of the 200 fibres measured for diameter. In addition

to the single fibre tests, 20 samples of "yarn" were made up (See Appendix) from each fleece, consisting of 20 fibres under fairly uniform tension with 20 twists per inch of fibre length. All of the "yarn" was made from top. Strength determinations were made with the aid of the Deforden fibre tester under controlled atmospheric conditions of 70° F. and 65% relative humidity. A manual test of staples taken from many parts of the fleece at the time samples were drawn for grease determination disclosed no wool in any of the fleeces which commercially would be called tender.

The mean diameter and the mean breaking load of the fibres from each fleece are listed in Table 2.

TABLE 2

Sheep No.	Mid section diameter of 200 fibres.	Breaking load of 200 fibres	Breaking load "Yarn"	Mean length of staples from shoulder and thigh
Ewes	cm x 10-4	grams	grams	mm
3	16.55 ± .21	5.67 ± .14	83.9 ± 1.2	70
4	16.73 ± .23	6.09 ± .16	79.3 ± 1.6	66
5	13.18 ± .14	4.76 ± .14	76.2 ± 1.3	81
7	21.73 ± .30	6.58 ± .20	88.0 ± 1.5	68
9	19.13 ± .27	6.27 ± .15	93.7 ± 1.2	78
11	19.42 ± .33	6.44 ± .12	97.1 ± 1.5	64
12	18.02 ± .28	6.44 ± .22	108.7 ± 2.0	68
13	16.73 ± .30	6.67 ± .23	93.8 ± 1.9	62
15	20.86 ± .32	6.98 ± .22	117.9 ± 2.6	55
18	20.18 ± .22	5.77 ± .15	90.2 ± 1.7	62
19	16.30 ± .24	6.71 ± .14	95.4 ± 1.1	72
Rams				
A.	17.85 ± .26	5.37 ± .19	85.2 ± 1.7	59
B. 312	20.22 ± .21	5.75 ± .12	95.7 ± 1.5	77
C. 227	17.47 ± .29	5.16 ± .12	81.4 ± 1.6	67
D. 45	18.30 ± .38	5.12 ± .11	82.4 ± 1.7	70
E. 205	19.47 ± .30	5.65 ± .19	74.9 ± 1.9	78
F. 226	17.86 ± .29	5.48 ± .16	101.0 ± 1.6	78

The scoured fleeces were processed at the Lowell (Mass.) Textile Institute. The writer was assisted by the various specialists in the wool department of the Institute, and the head of the department, Prof. Edgar H. Barker, outlined the procedure to be followed, and gave technical advice on all phases of the experiment which involved the use of textile machinery.

Each fleece was weighed, spread out on a clean floor and sprayed with water in an amount equalling 25% of the weight of the fleece. It was then packed into a card sliver can, covered, and allowed to remain over night in order that the added moisture might become evenly diffused throughout the wool.

Carding

Using the breaker section of the card only, it was found that by having the card clothing in good condition and the setting carefully adjusted, it was possible to produce a satisfactory end which was reasonably free of neps. A worsted card would have been preferable, but it was feared that a single fleece would present much greater difficulty in carding on the worsted than on the woolen card. Furthermore, the end result desired was a comparison of fleeces, not the exact noil which might be expected under orthodox methods of mill practice.

The Bramwell feed was disengaged, so that only its feed sheet was geared to the machine. The card was thoroughly stripped and the clothing was flocked by feeding several pounds of fine, short wool through it. The machine was then allowed to run until no more wool was being removed by the doffer comb, a procedure followed for each fleece. While there is no doubt that some intermingling of the fibres of one fleece with those of the next took place, it is felt that the extent of such intermingling was negligible on a proportional weight basis. The feed sheet was marked off into three equal portions and the scoured stock was weighed out into pound packages and distributed on the feed sheet by hand. The sliver delivered by the card was naturally light at both ends, but it should be remembered that no attempt was made to produce a sliver sufficiently uniform to satisfy mill demands, because production of a commercial yarn was not contemplated as a part of the experiment. In carding, each fleece was given identical treatment and the set and speed of the card were the same for all.

Gilling

The card sliver was given four gillings on an intersecting gill box. As in carding, all fleeces were given the same treatment. Gilling and combing were accomplished under controlled humidification of about 76% and partially controlled temperature of 75° F. to 85° F.

Combing

Because of the short lengths of gilled sliver an old-style Heilmann comb accommodating 24 ends was used for the combing process. By dividing the sliver from one fleece into 15, 16, or 17 ends, the length of each was great enough to allow the comb to be operated properly. In combing the fine-wool fleeces involved in this study, an attempt was made to divide the sliver into 16 parts. Occasionally a short length or an extra long length gave one more or one less than the desired number, a factor of no importance in the efficiency of the Heilmann comb. The settings of the comb remained untouched during the combing of all the fleeces. The machine was set to make a high noil, on the assumption that the greater weights obtained would reduce the probable error in weighing.

Immediately upon the completion of combing each fleece, and before any significant changes in weight could possibly take place through atmospheric moisture changes, the top, noil, brush waste and flyings were weighed. Because it is customary to base all textile mill calculations on avoirdupois weights, that system was followed.

The percentage of noils was not based on the weight of the scoured fleece but upon the total weight of all products produced by the comb.

TABLE 3

Sheep No.	Top			Noil		Fly	Brush Waste	Total Noil
	Lbs.	Oz.	Dr.	Oz.	Dr.	Dr.	Dr.	Per cent
Ewes								
3	2	8	0	6	6½	4	¼	14.30
4	2	4	0	7	13	6	2	18.76
5	2	10	8	8	4	5	2	16.97
7	2	10	0	9	1	6	1	18.45
9	2	14	15	7	8	7	1	14.56
11	3	3	8	7	14	9	4	14.44
12	3	14	0	8	0	7	1	12.06
13	2	6	6	8	8	4	2	18.78
15	2	8	0	4	11	6	1½	11.42
18	3	2	12	5	14	8	2	11.35
19	3	1	8	6	7	8	2	12.49
Rams								
A	3	0	8	13	5	10	2	22.48
B 312	3	9	4	7	8	4	½	11.97
C 227	2	15	0	8	0	6½	2	15.34
D 45	3	2	8	8	2	6	2	14.59
E 205	3	1	4	8	11	7½	1½	15.79
F 226	3	3	8	11	3	12	2	18.98

Discussion of Results

Table 3 indicates that the fleeces, while of similar origin, and produced under strictly comparable conditions, exhibited fairly large differences in the percentage of noil produced by the combing process. A reconciliation of the data on the percentage of noil with the data in Tables 1 and 2 is possible only in showing general trends.

There can be little doubt that a fleece with weak fibre should produce a higher noil than a similar fleece with strong fibre. Both carding and combing involve stress on the fibre with consequent breakage and a fairly large proportion of the broken ends of fibres should appear as noil. In these data, however, the mean breaking load of 200 single fibres proved a rather unreliable index of the percentage of noil. The argument may be advanced that 200 fibres is insufficient and that a better test would be 200 fibres from each of 8 or 10 parts of the fleece. The time required to break this number of single fibres is so great that, considering the number of fleeces involved, it would be impracticable to attempt it. A test of 200 fibres for fineness and breaking load is not out of line with numbers used by other investigators working with fine wools. Spöttel [5] found the measurement of 40 fibres sufficient to determine the mean fibre diameter of the finest and most uniform Merino wool within one micron and suggested that other kinds of wool (presumably those from other breeds of sheep), might necessitate the measurement of up to 500 fibres. Barker [6] cites the fact that from 100 to 300 fibres of Merino wool were measured at Halle to determine fineness. Burns [7] and Davenport and Ritzman [8] used 100 fibres. It would seem logical to assume that any number of fibres

sufficient to determine fineness with reasonable accuracy might also be used to determine breaking load.

In this experiment the breaking load of 20 strands of "yarn" provided a somewhat better idea of the strength of fibre, as indicated by the percentage of noil, than the single fibre test.

In view of the well known fact that fibre strength is directly correlated with fibre diameter, it is logical to assume that under identical conditions of fleece growth and subsequent treatment, the finer fleeces will be the weaker ones and will consequently produce a greater proportion of noil. Arranging the fleeces according to fineness shows that most of those which were relatively coarse (Nos. 15, 18, 7, 9, 11) produced a low noil, while most of the fleeces with high noil were among the finer ones (Nos. 3, 4, 5, 13, 19). The correlation is not high but it serves to indicate a trend and perhaps to cloud the reliability of the breaking load tests on 200 single fibres.

The noil produced by the fleeces with exceptional crimp, as compared with those poor in crimp, shows a general trend toward a higher noil from the well crimped fleeces. A similar general trend is found toward higher noil from greasier fleeces (of Nos. 4, 5, 12, 13 with Nos. 9, 15, 18, 19). Crimp is generally indicative of fineness of fibre although the relationship is not always strictly reliable when applied to individual fleeces.[9] Grease content may not be related to fineness.[3]

Length of staple in this experiment was apparently not related to the percentage of noil. Here the factor of individuality or genetic constitution may be so strong as to obscure the general relationship of fineness to length. The percentage of noil in these tests was not influenced by the sex of the animal.

Characteristics of the Top

While the percentage of noil from wool is of great importance, of equal importance is the uniformity of length of fibre in the top. The behavior of the top when "pulled," its so-called "drag," and its feeling likewise contribute to or detract from its value and adaptability for yarn manufacture. Each lot of top produced from the fleeces in this experiment was examined by the superintendent of top making in a large worsted mill. Under his direction also each lot was stapled with the mechanical stapling device used to test commercial lots produced by the mill. The principle of a similar apparatus and the interpretation of the results which it yields have been described in detail by Klinger.[10]

A study of the graphs thus obtained indicates that for the ewe fleeces No. 15 is the best top of the lot, followed by No. 18 and No. 4, while the least desirable lots are Nos. 9, 3, and 19 in the order named. Of these two groups No. 15 was the only one characterized as "a good spinning top" before the stapling was done. No. 18 and No. 4 were described as "fairly good" by the examining expert, while Nos. 9, 3, and 19 were found to be wasty and without proper drag. In this test the character of the top was not related to the percentage of noil, nor was it influenced by the length of staple as determined by shoulder and thigh samples.

Experimental

GROUP II.—Combing Test of Romney Marsh Fleeces Produced Under Varying Planes of Nutrition.

A similar combing test was applied to 12 fleeces produced in an experiment to determine the influence of the plane of nutrition on the wool fibres. A preliminary test on three Romney Marsh wethers indicated large differences in the character of the top and in the percentage of noil produced by the same animals under varying dietary regimens. In this preliminary experiment, the wethers were carried for six months on a supermaintenance ration, followed by six months on a maintenance ration, and a third period of six months on a submaintenance ration. The sheep were shorn at the termination of each six-month period and the fleeces resulting from the first and third periods were combed as two lots. The details of this work, with the exception of data relating to the combing test, were described in a previous paper.[11] The wool was scoured in the laboratory at the University and combed at the Lowell Textile Institute through the courtesy of the staff of the wool department of the Institute. Table 4 shows the results of combing the three fleeces representing the supermaintenance ration, and the three fleeces from the same animals on a submaintenance ration.

Wool Produced on Submaintenance Diet

Table 4 shows that the wool produced on the submaintenance diet gave about 71% greater weight of combined noil, brush waste and flyings than fleeces from the same animals grown during an identical period of time on a supermaintenance ration. The top was not stapled mechanically, but manual stapling showed that the top resulting from the supermaintenance ration was greatly superior to that produced on the deficient nutritional plane.

TABLE 4

Combing test of Romney Marsh wether fleeces produced by supermaintenance and submaintenance rations

	Total clean Wt. of 3 fleeces			Per cent of comb products				Total Noil
	Lbs.	Oz.	Dr.	Top	Noil	Brush waste	Fly	per cent
Supermaintenance ration	15	9	8	95.48	2.97	.32	1.23	4.52
Submaintenance ration	5	5	0	92.25	6.94	.18	.63	7.75

The second experiment, similar to that just described, was conducted with four Romney Marsh and two Rambouillet wethers. As in the first trial, the animals were shorn at the beginning and then fed for six-month periods on supermaintenance, maintenance and submaintenance rations.

The supermaintenance ration consisted of alfalfa hay and rolled barley, the maintenance ration of alfalfa hay, and the submaintenance ration of alfalfa hay limited in amount to cause a gradual decline in body weight. The wethers were shorn at the termination of each period. The fleeces were scoured in the laboratory and taken to the Lowell Textile Institute where each fleece was combed individually. Adjustments and settings of the machines were determined for what was considered the poorest fleece of the lot, and after that each fleece from that breed received the same treatment in the card, intersecting gill box and French comb, except that the tension and drawing-off mechanism of the comb was regulated to suit the individual fleece.

The Rambouillet fleeces grown in six-month periods under the various dietary regimens were so short in staple that it was found impossible to bring off a continuous sliver from the comb, and the results of combing these fleeces were such as to warrant their elimination from this discussion.

No comparison should be made between the percentage of noils obtained from Group I and Group II. The fibre from the Romney Marsh is so much coarser and stronger than that of the Rambouillet that even a poorly-grown Romney Marsh fleece might produce less noil than a well-grown fleece from a fine wool sheep.

TABLE 5

Combing test of fleeces grown under various nutritional regimens

Sheep No.	Top			Noil			Brush waste		Fly	Total Noil
	Lbs.	Oz.	Dr.	Lbs.	Oz.	Dr.	Oz.	Dr.	Dr.	Per cent
1387										
Supermaintenance	3	13	4	0	2	5	0	4	10	4.95
Maintenance	4	1	8	0	1	7	0	6	9	3.50
Submaintenance	1	2	12	0	2	5	0	1	3	12.02
1390										
Supermaintenance	4	7	12	0	2	9	0	6	14	5.04
Maintenance	4	7	4	0	1	6	0	6	11	3.31
Submaintenance	3	9	0	0	2	0	0	4	8	6.29
1393										
Supermaintenance	4	6	0	0	1	9	0	6	14	3.86
Maintenance	4	0	4	0	1	0	0	5	10	2.93
Submaintenance	2	11	8	0	1	13	0	4½	8	5.63
1395										
Supermaintenance	3	5	4	0	3	9	0	2	9	7.39
Maintenance	3	11	0	0	2	8	0	3	11	5.41
Submaintenance	0	12	1	0	2	15	0	2	1	30.99

Table 5 shows that the Romney Marsh fleeces grown on the maintenance diet produced a lower total noil than those from the same animals on the supermaintenance regimen. This may possibly be explained by the fact that the maintenance ration kept the animals at essentially the same body weight as that at which they finished the supermaintenance period.

The wethers were yearlings at the beginning of the experiment and added both size and condition during the first period, gaining an average of 71% in body weight. During the maintenance period, although the body weight of each sheep remained practically level (average net change less than 1%), the animals were growing in stature and increasing in body surface. They lost the high condition built up during the first period, yet enjoyed a state of thrift which enabled them to produce a greater weight of clean wool.

TABLE 6

Sheep No.	Fleece Wt.		Mean midsection diameter of 200 fibres from shoulder	Breaking load of 200 fibres from shoulder	Breaking load of 20 samples of "yarn" 10 fibres each
	Grease	Scoured			
	Grams	Grams	cm. x 10^{-4}	grams	
	3000	1985	30.88 ± .37	24.08 ± .34	194 ± 4.5
1387	3010	2132	28.88 ± .46	22.26 ± .29	195 ± 5.1
	1261	865	19.38 ± .41	11.26 ± .18	93 ± 2.9
	3262	2325	38.43 ± .46	29.36 ± .48	261 ± 5.9
1390	3455	2583	33.78 ± .63	31.64 ± .43	263 ± 5.4
	1863	1355	26.16 ± .53	22.98 ± .30	179 ± 5.4
	3370	2259	44.30 ± .53	26.98 ± .34	246 ± 3.2
1393	3987	2768	37.49 ± .51	34.84 ± .45	273 ± 7.1
	2127	1453	32.99 ± .53	21.20 ± .21	184 ± 4.6
	2230	1739	33.60 ± .48	28.34 ± .31	220 ± 3.8
1395	2409	1905	28.17 ± .51	25.55 ± .30	215 ± 7.5
	827	568	18.29 ± .18	15.27 ± .19	91 ± 4.0

The percentage of total noil from the fleeces grown on the submaintenance diet was, without exception, greater than that produced by either of the two other nutritional planes. Nos. 1387 and 1395 reached a more advanced stage of emaciation than Nos. 1390 and 1393, suffered a marked diminution in fleece weight, and produced a much higher proportion of noil. Nos. 1387 and 1395 lost on an average 28.6% of their body weight; Nos. 1390 and 1393, 24.6%.

The midsection diameters of 200 fibres proved a poor index of the noil from the supermaintenance and maintenance fleeces, while the finer fibre produced on the submaintenance diet was reflected in a lower breaking stress and a higher noil. The "yarn" test proved fully as accurate as the single fibre test.

The top from each of the Romney fleeces was tested as previously described. No. 1387 yielded a better top on the supermaintenance ration, Nos. 1390 and 1395 a definitely superior top on the maintenance ration, while No. 1393 gave on both regimens a fair top, with possibly a slight advantage in favor of that grown during the maintenance period.

Before subjecting the top to the mechanical stapling device, each lot was given a serial number to hide its identity and was examined by the expert. The slivers were presented to him in lots of three, each lot representing the three fleeces from one sheep. In every case the top made from

the fleece grown on the supermaintenance ration was found to have a better "drag" than the other two. Those representing the submaintenance ration were found to be wasty and dull.

The submaintenance diet shows in each case a top decidedly inferior. Nos. 1387 and 1395, which suffered most from the effects of this diet, as indicated by their change in weight, also gave the poorest top.

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The writer wishes to express sincere thanks to Professors Edgar H. Barker, R. L. Brown, J. C. Lowe, and Mr. James H. Kennedy, Jr., of the Lowell Textile Institute, and to Mr. George C. Best of the Wood Worsted Mill, Lawrence, Mass., for their kindly interest and advice in carrying out this work. To Mr. Frank C. Clarke, who furnished the fine wool fleeces for the experiment and who has displayed a keen interest in wool research, the writer expresses gratitude.

Appendix

The technique for making "yarn" from groups of single fibres was the following: A piece of black or dark blue velvet about 6 × 8 in. is secured to a table with thumb tacks. Across this velvet are stretched horizontally two white threads, parallel with each other 1½ in. apart, the ends secured by thumb tacks. A piece of clear glass about 5 × 7 in. is laid over the cloth, causing the threads to appear as white lines under the glass. A second piece of velvet, about 6 × 12 in. is secured to the table and is used for laying out the fibres. Fibres are pulled out individually from the staple, taking them in sequence from the right side and using all fibres long enough to mount. Twenty fibres of fine wool was found a convenient number. They are then laid one on top of another until the entire number are together with one end of each coinciding as nearly as possible. The bundle is lifted up from the velvet with tweezers and placed on the glass plate. A drop of melted adhesive, made of 90% rosin and 10% beeswax, is applied to secure the upper end of the bundle on the glass at the point where the top thread crosses. One prong of the tweezers is then used to tease the 20 fibres into three groups of 6 or 7 each. A small camel hair brush is cut off square with shears until the hair is short enough to give it sufficient rigidity to take the crimp out of the wool when the small groups are stroked downward, away from the adhesive. By stroking the half dozen or so fibres alternately with the brush and the index finger of the opposite hand, reasonably uniform tension can be applied to the individual fibres. After bringing one group of the bundle into position the second is worked on and so on until the entire bundle has been "combed" with the camel hair brush. The bundle is now being held at the distal end with the adhesive and at the proximal end with the finger, and the tension on each of the 20 fibres is approximately the same. Without allowing the finger to slip, the proximal ends are then pushed upward causing the bundle to form an arch. A piece of light cardboard about ¼ × 1 in. is inserted under the fibres, and they are brought back to their previous straightened condition. The cardboard is oriented until its upper long edge just coincides with the

lower white thread. A tiny drop of the melted adhesive is put on both edges of the cardboard at the points of the fibre bundle intersections, leaving the proximal ends projecting below the cardboard like the tail of a comet. These ends are then grasped with the fingers of one hand and lifted up about an inch above the surface of the glass plate. The thumb and index finger of the other hand are used to revolve the cardboard 30 times, thus twisting the wool fibres. If the distance between the two threads has been set at 1½ in., turning the tiny cardboard through 30 revolutions is equivalent to 20 twists per in. After putting in the twist the fibre bundle is lowered until the cardboard makes contact with the glass plate, thus preventing it from untwisting. While in this position the hollow square of heavy paper, used in mounting fibres for the Deforden tester, is slipped under the twisted strand and the wax applied to hold the "yarn" in position. The fibre bundle is cut above and below the hollow square.

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Abstracts

This section is compiled under the direction of the Committee on Abstracts and Bibliography: Prof. E. R. Schwarz, Chairman, Dr. W. E. Emley, Prof. Louis A. Olney and M. W. Weiss.

I. Fibres (Synthetic and Natural) and Fibre Analysis

Cotton Hybridizing: A New Technique in. Clifton C. Doak, *Jnl. of Hered.*, May, 1934, P. 201–4.

A method of emasculating cotton flowers by removal of corolla and androecium in a single piece is here described. This technique, when combined with the substitution of a soda straw for the customary paper bag, can claim the advantages of being faster and simpler, as well as physiologically and genetically less objectionable, than the method now in use. (S)

Viscose Rayon: Strengthening—in the Dry and Wet States. V. I. Minaev and G. S. Pomerantz. *Iskusstvennoe Volokno* (*Artificial Fibre*), 1934, V. 5, No. 1, P. 31–2.

Preliminary tests in treating viscose with the Al salt of a fatty acid and CH_2O indicate considerable improvement in the strength of the dry and wet fibre. (Copied complete from *Chem. Abs.*, 1934, V. 28, P. 3583.) (W)

Wax Content of Indian Cottons: Note on the—with Special Reference to Their Feel. N. Ahmad and D. L. Sen. Indian Central Cotton Committee Tech. Lab., *Tech. Bull.* 18B, 6 pp. (1933); *Chem. Abs.*, 1934, V. 28, P. 3909; *J. T. I.*, April, 1934, P. T150–T155.

The wax occurring on cotton fibre, though present in extremely small quantities, plays an important part in the spinning, wetting, dyeing, and scouring processes. It has, besides, a direct bearing on its feel as estimated by a grader. The wax content of 11 Indian and 1 non-Indian cottons has been determined, principally with a view to correlating it with its degree of silkiness or harshness. The results obtained show that the wax content of Indian cottons may range from 0.229% to 0.468%, that the exotic varieties grown in India have, on the whole, a higher wax content than the indigenous types and that the subjective estimates of the feel of a cotton, made by different graders are likely to disagree among themselves and with the results of the wax determination tests. Comparing the reports of the graders with the results of the tests a tentative scale

is suggested in which the degree of silkiness of a cotton is expressed in terms of its wax content. (S)

II. Yarns and Fabrics

Cotton and Viscose: Influence of Sodium Hydroxide Solutions on Mixed Textiles of. A. Lomanovich and V. Marker. *Iskusstvennoe Volokno (Artificial Fibre)*, 1934, V. 5, No. 1, P. 48–9.

Cold treatment with NaOH up to 5° Bé. does not appreciably change cotton and viscose in the mixed fabrics. Mercerization of cotton-viscose mixts. is impossible, because of the difference in shrinkage. (Copied complete from *Chem. Abs.*, 1934, V. 28, P. 3591.) (W)

Cotton Cards Do Not Remove Short Fibre. Carl D. Brandt. *Tex. Wld.*, Aug., 1934, P. 73.

Describes a test conducted at Texas Technological College on "snapped" cottons, and shows staple diagrams and their tabulation analysis showing that there was more very short cotton in the card waste than was present in the cotton being processed. (C)

Spirality in Knitted Fabrics. W. Davis and C. H. Edwards. *J. T. I.*, March, 1934, P. T122–T132.

Spirality as the authors define it is the departure from a true verticality with the lengthwise rows of stitches known as wales. The evidence in the paper seems quite conclusive that the spirality of knitted fabrics is due to yarn twist; that it may be reasonably prevented by setting the yarn to render the twist in the yarn inoperative, prior to knitting, or by the use of suitably balanced double yarn. It is stated that the machine effect due to stationary cams and rotating cylinder is negligible as far as spirality is concerned. It is stated further that spirality increases uniformly with the twist in the yarn and takes the same direction. That the effect is greater for cross-bred yarns than for botany yarns of the same characteristics. The effect can be corrected temporarily by treatment of the fabric in the steam-press. The effect can be completely prevented by previous setting of the yarn in which case water setting is said to be more effective than steam setting. Where two ends of yarn are to be used, spirality will not be evident if the single yarns have equal and opposite twists. Further, suitably balanced two-fold or two-ply yarns can be constructed to give a fabric free from spirality. (S)

Twist Direction. E. D. Fowle. *Tex. Wld.*, Aug,. 1934, P. 59.

The author suggests that, instead of defining twist in yarn as "right and left," "irregular and reverse," "clockwise and anti-clockwise," it be defined as S or Z twist. "If the yarn is held with one end pointing toward the man conducting the test, and that end is revolved clockwise, the yarn has "Z twist" if it untwists, and "S twist" if it twists tighter. The author says that the idea was first suggested by Henry S. Tynan of the Tynan Throwing Co., and admits that it is a modification of a German idea. (C)

WEAR RESISTANCE OF FABRICS. (German.) *Mell. Textilber*, March, 1934, P. 122–26.

Poor wear resistance of fabrics cannot be attributed to any one cause, but is rather the result of many factors including the properties and treatment of the wool fibre according to this article. An interesting means of comparing worn samples (worn on the Schopper Abrasion Testing Machine) is outlined. (S)

WOOL RESEARCH RESULTS. Anon., *Tex. Mfr.*, May, 1934, P. 192–93.

Some practical results are enumerated of investigations made by the Wool Industries Association and include material on wool scouring, carding, wool oiling, drawing and spinning, yarn factors, spirality in knitted fabrics, crepe yarns, and weaving. (S)

WOOL TEXTILES: TESTING AND REFINISHING OF—BY THE CLOTHIER. Anon., *Tex. Mfr.*, May, 1934, P. 209–10.

The point of view of a clothier who has to make the fabrics into garments after his own shrinking and refinishing. A discussion of fabric tests, wearing qualities, shrinking and refinishing, and uniformity and fastness from the standpoint of the manufacturer, and taken from *Fiber and Fabric*. An abstract of an address by J. J. Burns and C. J. Wilson to the U. S. National Association of Textile Dyers and Finishers. The procedures reported are those of Kuppenheimer. (S)

III. CHEMICAL AND OTHER PROCESSING (NOT OTHERWISE CLASSIFIED)

AMINO CELLULOSE. S. Malowan. *Kunststoffe*, March, 1934, P. 53–5.

A review of the patent and scientific literature on the introduction of nitrogen, especially basic nitrogen, into the cellulose molecule is given. Products containing small amounts of nitrogen are said to be obtained by treating cellulose esters or ethers with ammonium hydroxide, pyridine, or aniline. More nitrogen is introduced by using cyanogen derivatives. Using soda cellulose and cyanogen chloride, a product is obtained in 200% weight yield on the cotton which contains 11.7% nitrogen and 4.5% chloride. From solvent action the author concludes that the product is not a cyanogen derivative. The amino celluloses are said to be dyed as easily and strongly as wool with acid dyes. The celluloses, partially esterified with toluene sulfonic acid and aminated, are dyed equally well by acid or basic dyes. (Copied complete from *Eastman Kodak Abs. Bull.*, April, 1934.) (S)

ALIZARIN TYPE COLORS: BRIGHTNESS OF. Ch. Sunder. *Rev. gen. mat. color.*, 1934, V. 38, P. 129–34.

Alkali or lime, sometimes found in the water or the dye, must be corrected lest the brightness be tarnished. The old theory of Ad. Schlieper is not supported. Castor oil if exposed to light for 30 days develops within itself carboxylic groups which will form Al mordants. The acid groups of sulfonated castor oil tend to neutralize the lime or alkali. (Copied complete from *Chem. Abs.*, 1934, V. 28, P. 3907.) (W)

AZO DYES: DETERMINATION OF—BY REDUCTION WITH TITANIUM TRICHLORIDE. V. G. Shaposhnikov and G. K. Geĭzer. *Anilin. Prom.*, 1933, V. 3, P. 445–53.

The method of detn. of azo dyes by titration with $TiCl_3$ proved to be unreliable and inconvenient. (Copied complete from *Chem. Abs.*, 1934, V. 28, P. 3589.) (W)

BLEACHING, COLORING AND FINISHING OF THE FINE COTTON FIBRES: RATIONAL TECHNIC OF. L. Bonnet. *Rev. gen. mat. color.*, 1934, V. 38, P. 154–60.

Operations to conserve the exquisite softness necessary are indicated. (Copied complete from *Chem. Abs.*, 1934, V. 28, P. 3907.) (W)

CATALYTIC DESTRUCTION OF DYED YARN BY BLEACHING. Karl Risch. *Mell. Textilber.*, 1934, V. 15, P. 169–70; *Chem. Abs.*, 1934, V. 28, P. 3907. (W)

CHEMISTRY AND TECHNOLOGY OF FIBROUS SUBSTANCES: SUMMARY OF RESEARCH ON THE—(BLEACHING, DYEING, PRINTING AND FINISHING). Published in Russian Magazines in 1917–1931. A. E. Porai-Koshitz. *J. Applied Chem.* (U. S. S. R.), 1933, V. 6, P. 764–8.

A bibliography with 145 references. (Copied Complete from *Chem. Abs.*, 1934, V. 28, P. 3907.) (W)

COLLOIDCHEMICAL PROPERTIES OF SULFUR DYES. Ludwig J. Belenky. *Kolloid-Z.*, 1934, V. 67, P. 79–87.

Diffusion measurements of Sulfur blue RL from a 0.25% leuco form soln. into gelatin showed a high dispersity not changed by the common addn. agents to the dye baths. The dispersity is diminished by ammonia. The particles are negatively charged and are unaffected by the salt addns. Wool and cotton are also negatively charged as shown by electroosmosis expt. The pH of the dye bath is lowered by addns. and by fibre and accounts for the decreased dye soly. and adsorption by the fibre. Hydrosols prepd. by careful oxidation of the leuco form possess no dyeing properties. (Copied complete from *Chem. Abs.*, 1934, V. 28, P. 3906.) (W)

DYEING CELLULOSE MATERIALS WITH REFERENCE TO THE STRUCTURE OF CELLULOSE. R. E. Rose. *Rayon and Mell. Tex. Mo.*, May, 1934, P. 51–3.

This is a continuation of an article appearing in the April issue of the same journal, page 36. The present account continues with the discussion of the character of the dyestuff, conditions of dyeing, and a brief summary including a statement of something of the nature of the so-called vat colors and the need for further research in this field. (S)

DYEING TEXTILES WITH COLORS RESISTANT TO ALCOHOLIC STAINS. George Rice. *Tex. Col.*, 1934, V. 56, P. 34, 60; *Chem. Abs.*, 1934, V. 28, P. 2909. (W)

DYEING WITH SUBSTANTIVE AND ACID DYES: DETERMINATION OF OPTIMUM TEMPERATURE FOR. N. I. Planovskii and E. K. Ruichkova. *Anilin. Prom.*, 1933, V. 3, P. 88–97.

A cotton fabric was dyed at temps. from 30° to the b. p. and a wool fabric at 70° to the b. p. under standard conditions; both the amt. of dye fixed by the fabric and the quality of the color were taken into account. Some substantive dyes (Anil Orange G, Anil Green 2B, etc.) give approx. the same shade at all temps., while others give varying shades (Anil Red F, Anil Violet B, etc.); others again, though giving equal intensity of coloring, give purer shades at higher temps. (Congo Red AT, Anil Fast Scarlet 4BS, etc.) or vice versa (Anil Orange R.). These differences could not be connected with the purity of the dye. On wool a few dyes (Benzopurpurin AT4B, Anil Orange C and G, Anil Green B) give the best results, at 90°, the rest at the b. p.; the shades obtained with some (Anil Black FF, etc.) vary considerably with the temp. Acid dyes invariably give better results at the b. p. as regards both intensity and purity of color. (Copied complete from *Chem. Abs.*, 1934, V. 28, P. 2189.) (W)

DYES: ACTION OF LIGHT UPON. Hanns Rein. *Angew. Chem.*, 1934, V. 47, P. 157–61.

Exptl. data are given on the action of light of different wave lengths upon various dyes. With equal conditions of exposure, the max. action of light occurs when the absorption of the dye and the light source coincide most closely in their wave lengths. The destructive action of daylight is due mainly to the abundant visible portion of the sun's spectrum. The ultra-violet absorbing, white and yellow substances form an exception, as their absorption lies almost exclusively in the ultra-violet range. The action of several addns. to increase light fastness is discussed. Most artificial light sources are entirely unsuited for comparative purposes. A series of eight specially selected wool dyes of decreasing fastness was established for finding the amt. of reacting light. These were tested by sunlight exposures at stations all over the earth, together with dyes of a cotton scale, and exhibited considerable superiority as a standard for comparing climatic influences upon dyes. (Copied complete from *Chem. Abs.*, 1934, V. 28, P. 3235.) (W)

STARCH VISCOSITY. Gordon G. Pierson. *Ind. & Eng. Chem. Analy. Ed.*, May 15, 1934; *Tex. Wld.*, Aug., 1934, P. 69.

Describes a new viscosity test, and shows the effect of cooking on the viscosity of various commercial starches. (C)

SOAKING SOLUTIONS: TAKE-UP VALUE OF. Herbert C. Roberts. *Tex. Wld.*, July, 1934, P. 73.

Describes a method, borrowed from the dairy industry, by which a Babcock milk tester can be used to estimate the approximate boil-off of a lot of silk while it is going through the plant, or can calculate the quantity of oil needed to replenish standing baths employed for soaking rayon. (C)

SODIUM PERBORATE AS A BLEACHING AGENT. A. Jones. *Dyer*, 1934, V. 70, P. 589–90; *Chem. Abs.*, 1934, V. 28, P. 2910. (W)

IV. Research Methods and Apparatus

Abrasion Testing of Knitted Textiles. W. Davis. *J. T. I.*, April, 1934, P. T133–T149.

The machine described is a vibrating arm carrying an abrading member which is covered with a standard wool overcoating. The material to be abraded is stretched under radially applied weight on a circular specimen above an inflated rubber diaphragm which can be blown up to variable pressures. The plots given with the paper show considerable variability from test to test under supposedly similar conditions on knit goods. Tests are continued until a hole appears in the fabric but there is nothing said about the size of the hole or how it is judged. On the whole the tests are crude and no specific details of value are evident. (S)

Cellulose Films: Electron Diffraction by. Jean J. Trillat. *Comptes Rendus*, March 12, 1934, P. 1025–27.

The author prepares very thin films of nitro-cellulose, cellulose acetate, and various other cellulose compounds by evaporation of the solution on a mercury surface. He obtains films of thickness of from 50 to 100 Angstrom units. These are placed in the path of a stream of electrons using voltages of from 20 to 50 kilovolts. Diffraction diagrams are obtained which are extremely sharp and which are quite different from those produced by the usual X-ray technique. It is found that a freshly prepared film studied immediately in the beam of electrons is in general amorphous and the diagram shows a series of halos. However, after a few hours there are deposited certain so-called micro-crystals which are arranged more or less at random. After several days or sometimes weeks the film is crystallized to its maximum degree and the crystal diagrams as illustrated in the article are obtained on a fluorescent screen. It is intended to use the same procedure for the study of rubber, various protein compounds and for gelatine. (S)

Color: An Electric Eye for. Anon. *Am. Dye Rptr.*, July 2, 1934, P. 367.

An abstract from the *Industrial Bulletin* of Arthur D. Little, Inc. The article, although brief, gives a rather comprehensive survey of the various types of color measuring instruments particularly those using photoelectric cells. The work starts with the consideration of Lovibond's first glass color standards for standardizing the color of beer and proceeds with this to a brief outline of such apparatus as the Hardy color analyzer and similar devices. (S)

Control of Mixes of Different Origin by a Determination of the Swelling Characteristics. (German.) Karl Küsebauch, *Mell. Textilber.*, May, 1934, P. 193–4.

A method, together with considerable tabulated data, is outlined for the determination of the swelling of cotton fibres according to a definite technique in a solution composed of potassium hydroxide and ammonia, as compared with a measurement made on a sample mounted in dehydrated glycerine. It is stated that the resulting figures give information about the probable value of the cotton for further dyeing and mercerization processes. (S)